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Review

Climate change in Malaysia: Trends, contributors, impacts, mitigation and adaptations

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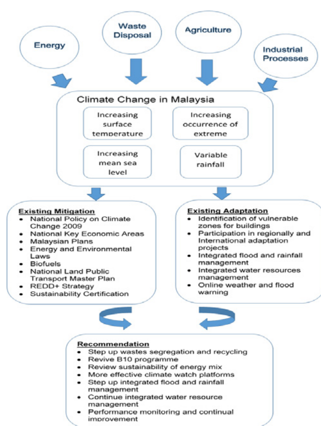
HIGHLIGHTS

- Surface temperatures, sea level and extreme weather events in Malaysia show increasing trends.
- More emphasis has been placed on mitigation of climate change than adaptations.
- Adaptation strategies which bridge the current gaps of adaptation are crucial.
- The review calls for continual improvement of mitigation and adaptation programmes.
- Stricter enforcement of laws and penalty is crucial for successful mitigation and adaptation.

GRAPHICAL ABSTRACT



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ABSTRACT

Purpose: This paper reviews the past and future trends of climate change in Malaysia, the major contributors of greenhouse gases and the impacts of climate change to Malaysia. It also reviews the mitigation and adaptations undertaken, and future strategies to manage the impacts of regional climate change.
Methodology: The review encompasses historical climate data comprising mean daily temperature, precipitation, mean sea level and occurrences of extreme weather events. Future climate projections have also been reviewed in addition to scholarly papers and news articles related to impacts, contributors, mitigation and adaptations in relation to climate change.
Findings: The review shows that annual mean temperature, occurrences of extreme weather events and mean sea level are rising while rainfall shows variability. Future projections point to continuous rise of temperature and mean sea level till the end of the 21st century, highly variable rainfall and increased frequency of extreme weather events. Climate change impacts particularly on agriculture, forestry, biodiversity, water resources, coastal and marine resources, public health and energy. The energy and waste management sectors are the major contributors to climate change. Mitigation of and adaptations to climate change in Malaysia revolve around policy setting, enactment of laws, formulation and implementation of plans and programmes, as well as global and regional collaborations, particularly for energy, water resources, agriculture and biodiversity. There are apparent shortcomings in continuous improvement and monitoring of the programmes as well as enforcement of the relevant laws.
Originality/value: This paper presents a comprehensive review of the major themes of climate change in Malaysia and recommends pertinent ways forward to fill the gaps of mitigation and adaptations already implemented.

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Contents

1. Introduction

Climate change is a global phenomenon and is particularly evident in the past three decades. The Intergovernmental Panel on Climate Change (IPCC), in its Fifth Assessment Report, reveals an increase of average global land and ocean temperature by 0.85 °C from 1880 to 2012. The IPCC is highly confident that the period between 1983 and 2012 was the warmest in the past 800 years (PCC-AR5-WG1, 2013).

While surface air temperature is most commonly used to elucidate climate change, sea level, sea surface temperature, arctic sea ice and the occurrence of extreme weather have also been monitored in tracking the phenomenon (Nakicenovic et al., 2000; PCC-AR5-WG1, 2013). Variation of sea level as a result of climate change is measured using the global mean sea level (GMSL). The rate of sea level variation has shifted from low during the late Holocene in the range of tenths of mm per year, to high presently in the order of mm per year, owing primarily to ocean thermal expansion and glacier melting. Warming ocean has very likely resulted in sea level rise of 0.8 mm/year from 1971 to 2010. The global glaciers have been retracting at a likely rate of 226 Gt/year from 1971 to 2009 and 301 Gt/year between 2005 and 2009. The glacial shrinkage has reached the tipping point and will continue even after the global surface temperature ceases to increase. Similarly, the Greenland ice sheet has been confidently diminishing over the last 20 years (PCC-AR5-WG1, 2013; Kamaruddin et al., 2016).

Warming of the upper ocean was observed between 1971 and 2010 and it is likely that ocean warming had extended to a depth ranging from 700 m to 2000 m from the sea surface between 1957 and 2009. Climate change also leads to extreme weather events in the atmosphere and on the ocean. A highly probable increase of the number of warm days and nights was predicted between 1951 and 2010. Heat wave had occurred more frequently in Europe, Asia and Australia in mid-20th century (PCC-AR5-WG1, 2013). Floods of greater magnitude have also been reported in eastern Asia, northern and central Europe, and the western Mediterranean in the past five centuries. On the ocean, increased frequency of high sea level events have been anticipated since 1970 (Nakicenovic et al., 2000).

Being a global phenomenon, there has been increasing interest to look at how climate change and its impacts unfold regionally, including in Malaysia. Malaysia is a Southeast Asian country consisting of two regions, i.e. the Peninsular Malaysia and the Malaysian Borneo. The country has a total land area of 330,803km^2 and an estimated population of 32 million in 2017 (Ab Rahman et al., 2013). The country experiences equatorial climate characterized by hot and humid weather all year round. The annual climate variability is closely tied to the Southwest and the Northeast Monsoons. The Southwest Monsoon occurs in the months of April to September while the Northeast Monsoon occurs from October to March. The Southwest Monsoon features drier weather with less rainfall compared to the Northeast Monsoon which brings more precipitation (Kwan et al., 2013).

Malaysia has experienced warming and rainfall irregularities particularly in the last two decades, thus, garnering much attention in the study of climate trends and the implications. Sammathuria and Ling (2009) investigated the historical annual mean of daily temperatures as well as annual precipitation for selected regions in Malaysia. The study also included simulations of temperature and rainfall anomalies. The Malaysian Meteorological Department (2009) published a report on climate change scenarios for Malaysia but used data from limited stations to demonstrate the past temperature and rainfall trends. The report focused on simulating regional climate variations.

Much of the research on climate change in Malaysia is dedicated to studying the effects of climate change rather than examining the historical and future trends, and a large proportion of the studies is related to agriculture. A plausible reason that impacts of climate change on agriculture have received much attention in Malaysia is its importance as a major national Gross Domestic Product (GDP) contributor (Department of Statistics Malaysia, 2018). In 2016, agriculture sector comprised 8.1% of the GDP with paddy recorded the second largest agricultural production after oil palm (Department of Statistics Malaysia, 2018). Besides, agriculture is highly dependent on climatic factors, rendering climate change a significant concern to the sector.

The interest in the effect of climate change on paddy was immense with numerous dedicated research. Vaghefi et al. (2011) examined the economic implication of climate change on rice production in Malaysia while Alam et al. (2012) investigated adaptability of paddy farmers to climate change by means of questionnaire survey conducted on 198 paddy farmers in Selangor Malaysia. Prior to this, Alam et al. (2010) also produced guidelines in determining climate change adaptation approach for the Malaysian agricultural sector in general. An earlier study by Matthews et al. (1995) modelled the impact of climate change on rice production in Asia, including Malaysia, with little highlight on adaptation strategies. A statistical approach was adopted by Murad et al. (2010) to establish the correlation between climate change and agricultural growth within a defined duration which the authors found were negative but insignificant. However, the study was not paddy-specific.

With oil palm holding the largest agricultural yield in Malaysia, the research of climate change's impacts on oil palm cultivation does not garner proportional interest as that on paddy. Oil palm cultivation is controversial in the sense that it has been regarded as a culprit of tropical deforestation (Fitzherbert et al., 2008) and contributor of climate change due to cultivation on carbon-dense ecosystems such as peat swamp (Butler and Laurance, 2009). Beyond the agricultural sector, a study on social adaptation of fishermen due to climate change have

been conducted (Md Shaffril et al., 2013). Generally, there is still a lack of research on climate change's implications on the Malaysian fisheries.

Also garnering much research attention is the variations brought by climate change on water resources. Shaaban et al. (2010) predicted the changes of water resources in Peninsular Malaysia based on future projections of climate change while Tan et al. (2015) studied how climate variations affected hydrological components in the Johor River Basin, in conjunction with land uses. Further to change prediction, Khailani and Perera (2013) promulgated the need to incorporate disaster resilience in local development planning as adaptation to climate change. In general, though there is a cornucopia of research conducted at global level on the theme of climate change and adaptation, such research is significantly less for the Malaysian context.

This study therefore, attempts to highlight the latest trends and projections of climate change in Malaysia and provides a review of its impacts, mitigation and adaptations regionally. It also recommends mitigating and adapting strategies based on the gaps identified in the current programmes to manage climate change.

2. Methodology

Variations of surface air temperature, sea level, sea surface temperature, arctic sea ice and precipitation as well as occurrences of extreme weather are the common parameters employed to track the unfolding of climate change (Nakicenovic et al., 2000; PCC-AR5-WG1, 2013). In a tropical country like Malaysia, changes of arctic sea ice become irrelevant. This study reviews historical temperature and sea level data at selected stations to capture the trend of climate change in the Malaysian Borneo and major regions of the Peninsular Malaysia. Selection of the stations was based on comprehensiveness of online data provided by the National Climatic Data Center, which is operated by the National Oceanic and Atmospheric Administration, US (NOAA, 2018). Climatic data of the NOAA have been collected worldwide via various modes such as the Global Telecommunication System and Automated Weather Network. At least one station with comprehensive climatic data in each major region of Malaysia has been selected. Selected stations in the Malaysian Borneo were Kuching and Kota Kinabalu to capture the climate variations in the states of Sarawak and Sabah respectively. In the Peninsular Malaysia, the chosen stations were Kuantan located on the east coast, Malacca on the west coast and Subang in the Federal Territory of Kuala Lumpur.

Data of average precipitation and rainy days were extracted from the website of the World Weather Online whose data have been reliably sourced from global weather satellite, world meteorological organization and global telecommunication system (WorldWeatherOnline, 2018). Data of mean sea level were sourced from the records of tide gauges maintained by the Permanent Service of Mean Sea Level (PSMSL) with data completeness of at least 95% (PSMSL, 2018).

The website of the Malaysian Meteorological Department was visited for records of major floods and extreme events. Subsequently, the historical climatic trends were graphically presented. To ensure validity of the climatic and sea level data, the data gathered and the trends yielded were compared against those reported in the literature, particularly by the Malaysian Meteorological Department (2009) and other studies on historical climatic trends (Sammathuria and Ling, 2009; Kwan et al., 2013; Syafrina et al., 2017).

Literature related to projections of future climate change, particularly the mean temperature, average precipitation and mean sea level have been reviewed to examine the consistency of such projections. This paper then reports the agreement and discrepancy between the projections based on the review, without conducting simulations of the future climatic trends. The review showed generally two models of simulating future trends of climate change, i.e. the General Circulation Models (GCM) and the Providing Regional Climates for Impacts Studies Models (PRECIS). The literature review also includes extreme weather events, impacts of climate change, the major contributors of greenhouse gases as well as the mitigation of and adaptations to climate change, for the context of Malaysia. Multiple sources of information encompassing primarily journal articles and secondarily technical, government and news reports have been reviewed to provide comprehensive accounts and more diverse perspectives of the review genres.

3. Results and discussion

3.1. Mean daily temperature

Fig. 1A shows that the yearly moving average of mean daily temperature in Kota Kinabalu was on an uptrend, fluctuating between 26 °C and 28.5 °C. Similar trend was observed in other stations. The range of temperature fluctuation was between 25.5 °C to 27.5 °C in Kuching (Fig. 1B), between slightly below 26 °C and 28.5 °C in Malacca (Fig. 1C), between 25 °C and 28 °C in Kuantan (Fig. 1D), and from slightly below 26 °C to 28.7 °C in Subang Jaya (Fig. 1E).

The magnitude of increase in the annual moving average of mean daily temperature, as indicated by the gradient of the linear trendline (Fig. 1), was lowest for Kuching, followed by Kota Kinabalu, Malacca, Kuantan and Subang Jaya in increasing order. This agrees with the findings of the Malaysian Meteorological Department (2009) with Kuching showing the least increase in temperature due to slower rate of development. The gradients indicated by the linear trendlines, however, do not signify the actual rate of annual mean temperature increase. The reported approximate rate of mean temperature increase was 0.25 °C per decade for the peninsular Malaysia, 0.20 °C per decade for Sabah and 0.14 °C per decade for Sarawak (NRE, 2015).

The temperature spikes in 1972, 1972, 1991, 1997–1998 and 2015–2016 were due to strong El Nino with the 2015–2016 event being one of the strongest (see Fig. 1A to E). The frequency of El Nino has been more pronounced in the last 45 years (Sammathuria and Ling, 2009).

3.2. Extreme weather

The extreme weather events in Malaysia are characterized by days of high temperature, high rainfall, dry spell, thunderstorm and strong winds. The past decades have seen increasing occurrence of extreme weather events. The worst floods were recorded in the southern peninsular Malaysia during the 2006/2007 monsoon. Days with extreme rainfall events have been on the rise since 1980s. Extreme wind events and number of annual thunderstorm days have also been increasingly reported (Sammathuria and Ling, 2009). The increasing hot years are evident from the temperature surges in Fig. 1A–E under the influence of El Nino (Malaysia Meteorological Department, 2009). The co-occurrence of dry spell and heavy rainfall within the same year is an emerging weather pattern in Malaysia (Khor, 2015). Tables 1 and 2 show increasing records of flood and extreme weather event in the 21st century. This is also parallel to the global increment of extreme weather, especially floods and storms (see Fig. 2).

3.3. Rainfall

The historical rainfall data shows high variability which is consistent with the findings of other studies (Malaysian Meteorological Department, 2009; Sammathuria and Ling, 2009; Loh et al., 2016). Fig. 3A shows the average monthly rainfall of Kota Kinabalu was generally below 500 mm except between 2009 and mid-2010 where the monthly rainfall peaked in the mid-2010. Similar trend was also observed in Kuching (Fig. 3B) with high rainfall recorded between 2009 and mid-2010. However, the rainfall peaked at the end of 2009 and early 2010. In other locations, the rainfall recorded at the end of 2009 was also the highest, but the annual rainfall peaks are more obvious particularly in Malacca on the west coast of Peninsular Malaysia (Fig. 3C) and Kuantan on the east coast (Fig. 3D). The annual rainfall variation is also demonstrated in Fig. 4 showing the average precipitation of Malaysia in general. The

annual rainfall upsurge is due to the northeast monsoon characterized by strong northeasterly and easterly winds blowing from the western Pacific to the South China Sea in the months of November till February, bringing in moisture from the region (Chang et al., 2005). Higher inter-annual precipitation, for instance in 2009 and 2010, could be effected by the La Nina episodes during which sea surface temperatures in the east-central Equatorial Pacific drop below average (Ab Rahman et al., 2013).

Fig. 3A–E generally show that higher average precipitation is associated with increased days of rain. However, rain intensity in the rainy days differs with rainy days during the northeast monsoon season having higher rain intensity. Despite the variability of average precipitation, Mayowa et al. (2015) reported significant increase in annual rainfall and northeast monsoon rainfall in the study areas located on the east coast of Peninsular Malaysia at 95% and 90% confidence levels respectively over the period of 1971–2010. The study also revealed an increase of days with more than 20 mm rainfall by 1.5 per decade in the same period.

3.4. Mean sea level

The mean sea levels in the Malaysian waters have been on the rise and this is clearly shown in Fig. 5. Fig. 5C shows a sharp fall in the sea level at Lahad Datu, Sabah in 2015 but the overall trend is a rising one. Overall, the total average sea level in Malaysia has been rising at 3.67 $\pm$ 0.15 mm/year based on the analysis of tidal data from 1984 to 2013 (Kamaruddin et al., 2016). This is higher than projected global sea level rise of 1.7–3.1 mm/year due to local climate and topographical conditions. Ercan et al. (2013) projected the sea level on the coast of the Peninsular Malaysia and the coast of Sabah-Sarawak to rise by 0.517 m and 1.064 m respectively by 2100.

3.5. Future predictions of climate change

The future will see climate change intensifying. Projections of climate change have been conducted in various studies using the General Circulation Models (GCM), also known as the Global Climate Models and the Providing Regional Climates for Impacts Studies Models (PRECIS). The PRECIS provides high-resolution simulation of climate change for any region of the world, even for islands which are beyond the resolution of GCM (Loh et al., 2016). To compensate for a lack of resolution of the GCM, the regional climate model (RCM) which gives greater spatial resolution could be applied to the outputs of GCM in a process called dynamic downscaling (Rummukainen, 2015). For instance, the HadRM3P used by Kwan et al. (2013) to project changes of extreme weather events in Malaysia is a PRECIS-linked RCM.

The simulations pointed to a projected temperature rise of less than 4 °C till the end of the 21st century and a lack of definite trend for rainfall with increasing rainfall towards the end of the 21st century. Few simulation studies in Malaysia have considered different scenarios of GHGs emission, one of which is the study conducted by Loh et al. (2016) using emission scenarios of A2, A1B and B2 similar to those in the Special Report on Emissions Scenarios (SRES) (Nakicenovic et al., 2000). A1B is most commonly used in other climate projection studies in Malaysia (Malaysian Meteorological Department, 2009; Sammathuria and Ling, 2009; Kwan et al., 2013). The emission scenarios of SRES have been superseded by the Representative Concentration Pathways (RCPs) introduced in the IPCC fifth Assessment Report (PCC-AR5-WG1, 2013). There are four RCPs defined by the relative radiative forcing ranges in year 2100 with pre-industrial values as baseline (PCC-AR5-WG1, 2013). More recent simulation studies, for instance the one by Syafrina et al. (2017) has adopted the RCPs.

Generally, climate simulations also pointed to uncertainties in predicting future extreme weather events due to limitations of the

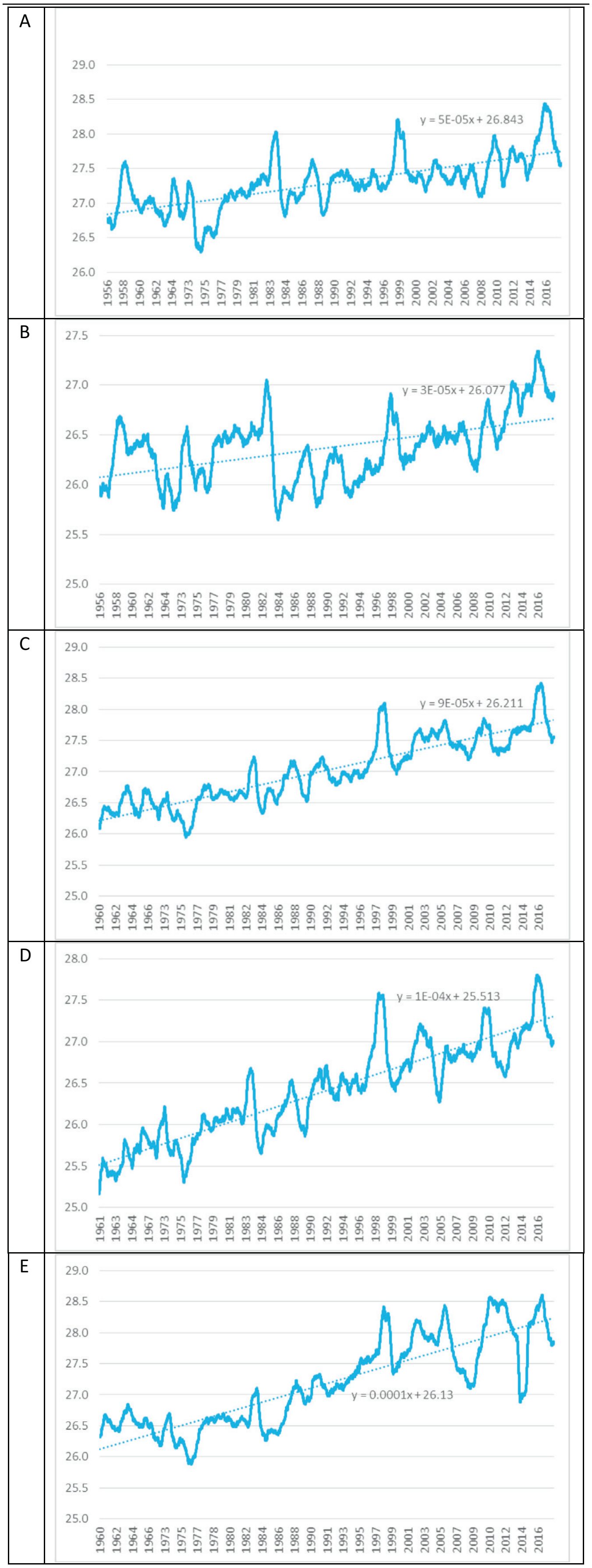


Fig. 1. Annual moving average of mean daily temperature in A) Kota Kinabalu (1956–2018); B) Kuching (1956–2018); C) Malacca (1960–2018); D) Kuantan (1961–2018) and E) Subang Jaya (1961–2018).

Table 1
Major floods in Malaysia (CFE-DM, 2016).

Date	Location	Description
January 1971	Kuala Lumpur, Malaysia	The worst in Malaysia since 1926 and resulted from heavy monsoon rains, the flood killed 32 people and affected 180,000 people.
December 2006–January 2007	Southeast Asian	The flood affected Johor badly and to a lower extent, Malacca, Pahang and Negeri Sembilan. It was caused by heavy rainfall due to Typhoon Utor.
October–November 2010	Thailand and North Malaysia	The flood affecting separate areas in Thailand and Malaysia was caused by unusually late monsoon moisture from the Bay of Bengal and the La Nina monsoon rainfall. The flood resulted in 232 deaths in Thailand and 4 deaths in Malaysia.
January–February 2014	Sabah, Malaysia	Various regions of Sabah including Menggatal, Penampang and Tuaran were flooded due to heavy rainfall and flash flooding.
December 2014–January 2015	Southeast Asia and South Asia	Floods in the Indonesia, West Malaysia, South Thailand and Sri Lanka were a result of the northeast monsoon, affecting more than 417,000 people.
January–February 2015	East Malaysia	Floods occurred in various regions of Sabah and Sarawak likely due to intensified northeast monsoon. Approximately 13,878 people were affected.
February–March 2016	Malaysia	Sarawak, Johor, Malacca and part of Negeri Sembilan were hit by floods due to heavy rainfall.
December 2016–early 2017	Southern Thailand	Flooding particularly in the southern Thailand also affected the states of Kelantan and Terengganu in Malaysia. The floods were caused by annual monsoon season and led to an estimated loss of USD 4 billion, mainly attributed to their impacts on agriculture, tourism and infrastructure.
November 2017	Penang, Malaysia	Flash flood forced approximately 3000 people to be evacuated in Penang, as the state was hit by strong wind and torrential rain lasting for hours, due to tropical cyclone (Reuters, 2017).
Jan 2018	Malaysia	The annual northeast monsoon brought heavy rain leading to floods especially in the states of Johor, Terengganu, Pahang and Sabah. The flood killed two in Pahang and caused about 12,000 people to be displaced nationwide (The Straits Times, 2018).

Table 2
Other extreme weather events in Malaysia (CFE-DM, 2016).

Date	Location	Description
26 December 2001	Southeastern Peninsular Malaysia	Tropical Storm Vamei formed on the South China Sea landed in Malaysia, causing flooding and landslides in the eastern Peninsular Malaysia
October–November 2014	Peninsular Malaysia	Kedah and Selangor were hit by episodes of EF3 tornado, each lasting for 10–15 min with wind speed up to 240 km/h. The frequent tornado formation was speculated to have been due to changes in monsoon. There had been precedence of tornado in Penang, Perlis and Selangor in 2010.
October 2017	Sabah, Malaysia	Typhoon Paolo developed from a tropical cyclone brushed by Sabah, bringing strong wind and rain across the state. Damages had been reported.
December 2017	Malaysian Borneo	Strong wind gushed through the west coast of Sabah, Sarawak and Labuan at 40–50 km/h due to Tropical Storm Kai-Tak originating in the Western Pacific Ocean.
February 2018	Penang, Malaysia	A small tornado reported in Penang caused damage to the roof of a building.

RCMs in predicting periodic ocean-atmospheric oscillations, particularly, the Indian Ocean Dipole (IOD) as well as the El Nino and La Nina which had been correlated with the extreme weather events in the past (also see Table 3).

3.6. Impacts of climate change

In Malaysia, seven sectors have been identified as vulnerable to the impacts of climate change, i.e. agriculture, forestry, biodiversity, water resources, coastal and marine resources, public health and energy. Nonetheless, much of the existing research focuses on studying the agricultural impacts of climate change, particularly the impacts of rice production.

An overall small to moderate reduction of agricultural productivity and yields has been reported (NRS, 2001). This was also echoed by Murad et al. (2010) that agricultural growth rate was negatively but weakly correlated to climate change score though a strong significant positive correlation was found between per capita CO_2 emission and agricultural production index, pointing to agriculture as a contributor of CO_2. The significant CO_2 emitters of the Malaysian agricultural practice

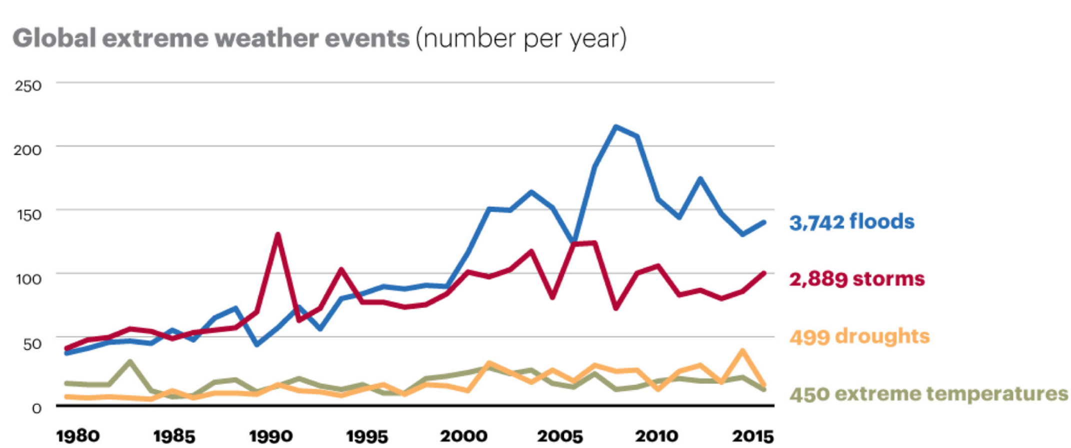


Fig. 2. Global extreme weather events (Laudicina and Peterson, 2015).

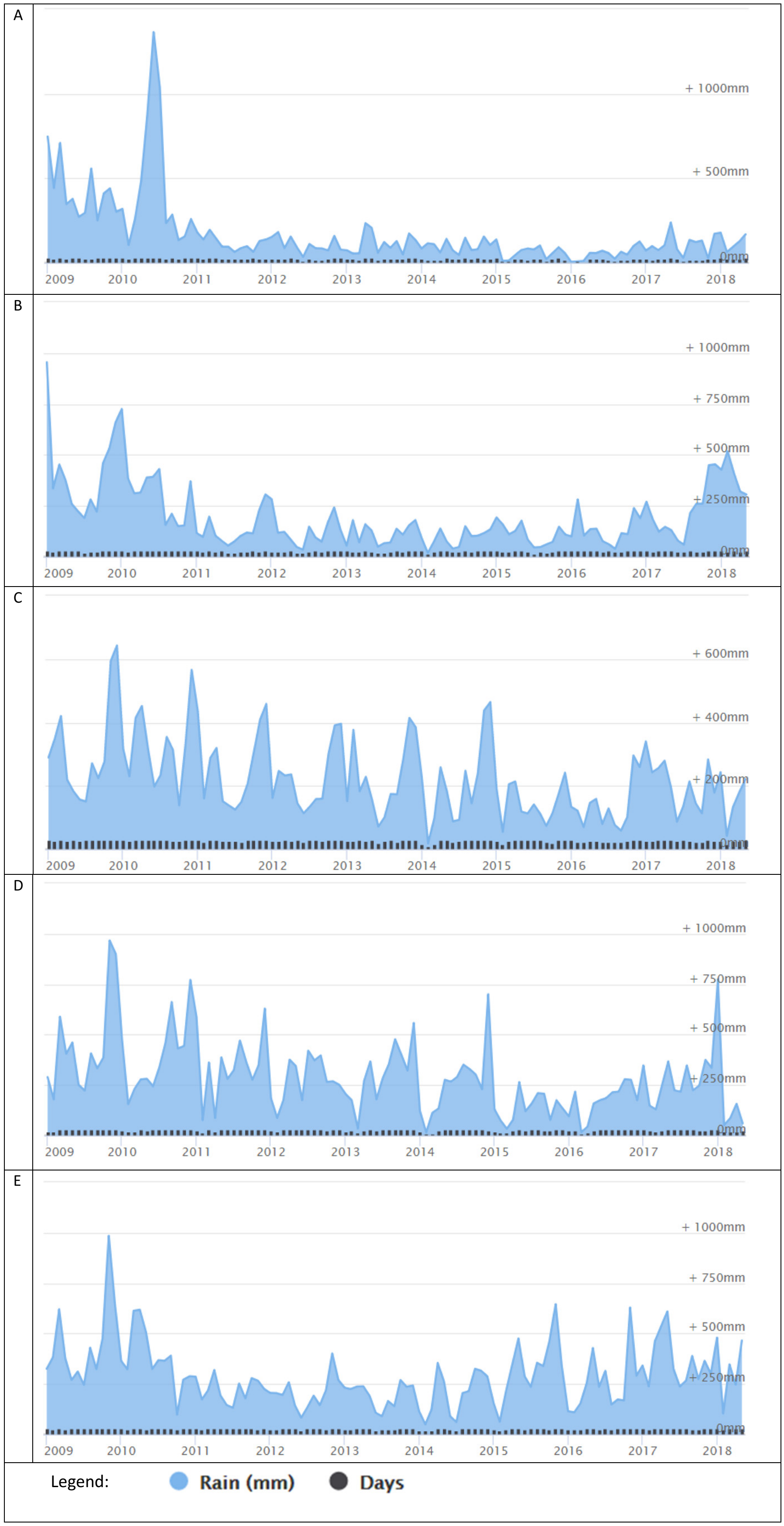


Fig. 3. Average Rainfall and Rainy Days of A) Kota Kinabalu; B) Kuching; C) Malacca; D) Kuantan and E) Kuala Lumpur (WorldWeatherOnline, 2018).

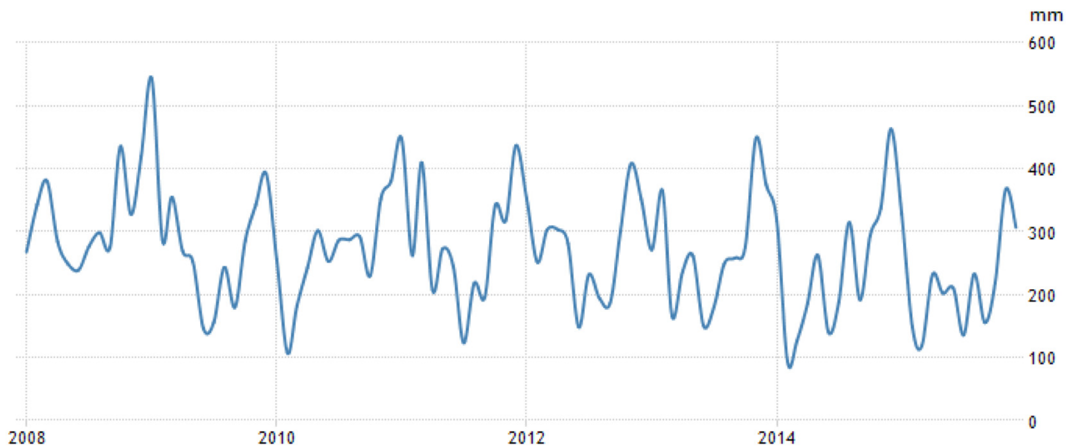


Fig. 4. Average precipitation of Malaysia (WorldWeatherOnline, 2018).

was not pinpointed but it raised concern on the sustainability of agricultural practices. While rising atmospheric CO_2 level is beneficial to C3 plant such as paddy with rate of photosynthesis dependent on CO_2 concentration, temperature increase beyond the tolerance limit of 26 °C counteracts photosynthesis and promotes respiration, hence slowing grain filling (Matthews et al., 1995). The projected future Malaysian climate change characterized by temperature rise and unexpected rainfall patterns does not favour grain production (Singh et al., 1996; Al-Amin and Siwar, 2008).

Vaghefi et al. (2011) estimated a yearly economic loss of RM162.53 million in the Malaysian rice industry based on simulated rice yield reduction of 0.36 t/ha with 2 °C increase in temperature and current CO_2 level of 383 ppm. However, an increase of CO_2 level at constant temperature rise in the simulation resulted in a greater fall of rice yield at 0.69 t/ha. This is contrary to the growth-promoting effect of higher CO_2 level on C3 plant (Matthews et al., 1995). The explanation provided was a seeming interaction between rice yield CO_2 and temperature but was not supported with physiological evidence (Vaghefi et al., 2011). Nonetheless, a study by Manalo et al. (1994) showed that a combination of CO_2 and temperature increase shortened the reproductive phase of lowland paddy cultivars and reduced flowering time. The study showed opposite effects of the respective increase in CO_2 and temperature on lowland paddy flowers' dry weight, with the former increasing the total dry weight and the latter showing the reverse. On a related note, climate change has been statistically found to relate significantly, either directly or indirectly, to food security of the Malaysian households on the east coast of the Peninsular Malaysia living at or below the poverty line (Alam et al., 2016).

Climate change is foreseen to aggravate high flow in the watersheds of Kelantan, Terengganu, Pahang and Perak during the Northeast monsoon and substantially reduce flow in the Selangor and Klang watersheds during the Southwest monsoon, between 2025 and 2050 (Shaaban et al., 2010). The change in flow has implications on properties, for instance structural damage caused by heavy rainfall, flooding and rainfall-induced landslides (Shahid et al., 2017). An obvious limitation of many local studies on the impact of climate change is a lack of support with historical data showing how warming and increased rainfall magnitude resulted in increased manifestation of impacts. In terms of fishery, Md Shaffril et al. (2013) reasoned that unstable climate reduces the days of fishing and poses greater risk to fishery activities. Though lacking statistical support, a study by Yaacob and Chau (2005) did reveal that fishermen in the east coast of the Peninsular Malaysia earned 9 to 32% less due to unstable weather patterns.

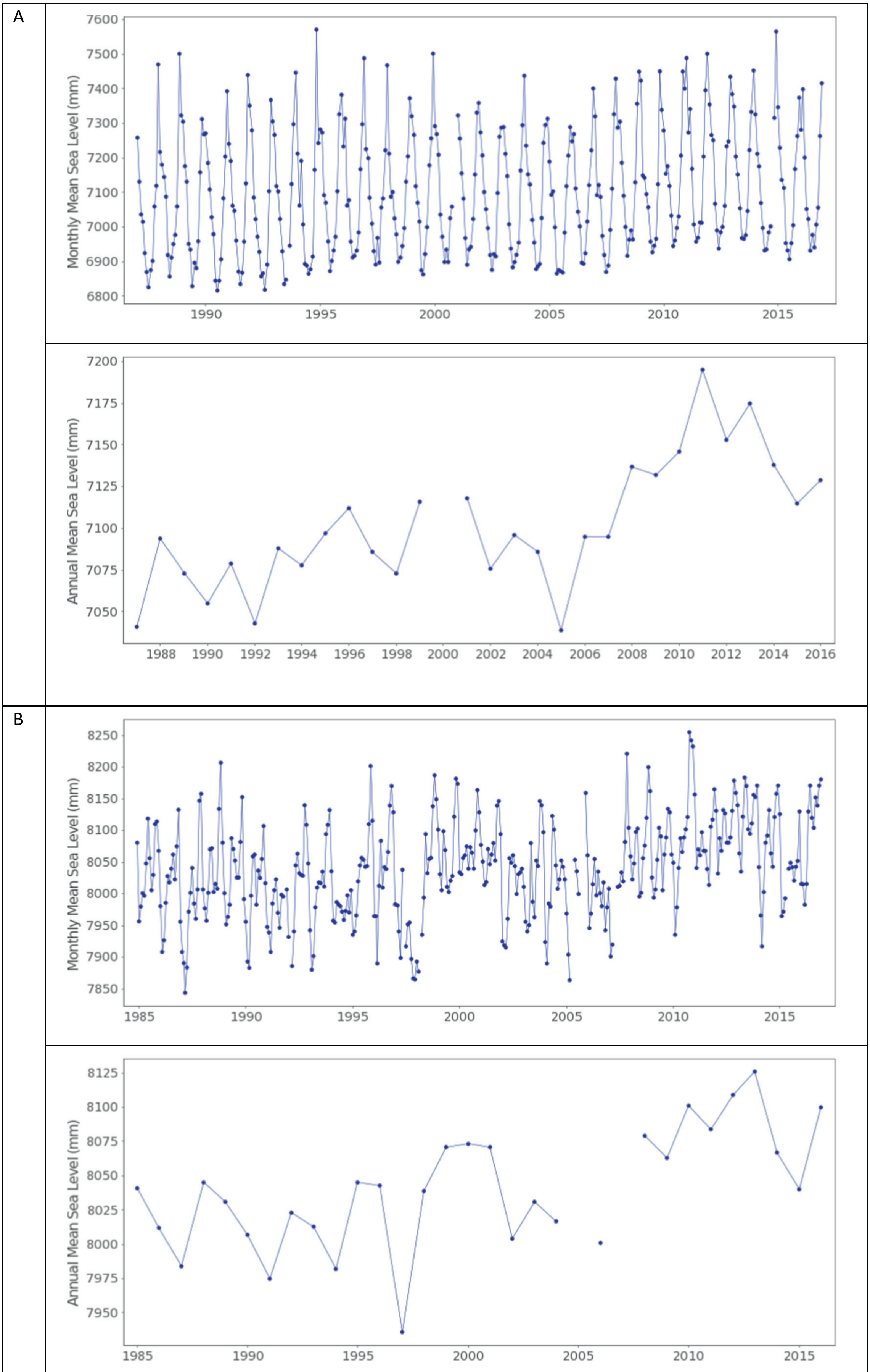
Climate change also impacts energy consumption on cooling of air-conditioned office building. Yau and Hasbi (2017) projected an increase of cooling load by 2.96%, 8.08% and 11.7% respectively in 2020, 2050 and 2080 from the baseline of 2000. With maximum cooling load of 297,000 KJ/h in 2000, the increase is translated to 305,000 KJ/h in 2020, 321,000 KJ/h in 2050 and 330,000 KJ/h in 2080. The rise of maximum cooling load is attributed to projected increase in outdoor temperature causing more heat to get into buildings via walls. The variations in temperature and rainfall as well the occurrences of fire and haze due to climate change also adversely affect tropical peatlands, particularly their potential to store carbon, thus, causing a potential shift of the peatlands from carbon sink to carbon source, which in turn, aggravates climate change (Lee et al., 2018).

Climate change is known to affect public health by increasing the transmission of mosquito-borne diseases such as dengue and expanding the affected zone (Naish et al., 2014). However, very few research has been dedicated locally to investigate how the occurrences of such diseases and the zone of impact have altered with the changing climate trends. A review by Alhoot et al. (2016) revealed a potential increase of malarial cases by 15% with the rise in ambient temperature by 1.5 °C in 2050 and the projection was subject to other variables such as increase in precipitation and saline water intrusion. The review also highlighted the positive correlation between rainfall and dengue, and postulated that climate change characterized by increased rainfall time and surface temperature favoured the propagation and spread of dengue viruses. The review did not draw a conclusive relation on how climate change affected the occurrences of food and waterborne diseases.

3.7. Major emitters of greenhouse gases

CO_2 is a greenhouse gas along with methane, water vapour, nitrous oxide and ozone (PCC-AR5-WG1, 2013). While important for the balancing of Earth's surface temperature, anthropogenic emission of greenhouse gases (GHGs) has largely accounted for global warming, hence the extreme weather and other consequences associated with climate change (PCC-AR5-WG1, 2013).

In Malaysia, the total emission of GHGs is on the rise with the energy industries leading the emission (see Fig. 6). In 2011, energy sector contributed to 76% of the total emission, followed by waste disposal (12%) and industrial processes (6%). The agricultural sector contributed 5% of the total GHGs emission (NRE, 2015). Key greenhouse gas emitters of the energy sector included road transportation, power generation, fugitive emissions from oil and gas operation, fuel manufacturing and processing, and activities of other sectors involving energy production, while those of the industrial processes were cement production, limestone and dolomite use, as well as iron and steel industry. For waste disposal, solid waste disposal sites and treatment of wastewater from palm oil mills were the major contributors of GHGs, particularly methane. Agricultural soil was the primary source of nitrous oxides (NRE, 2015).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Monthly Mean Sea Level (mm)
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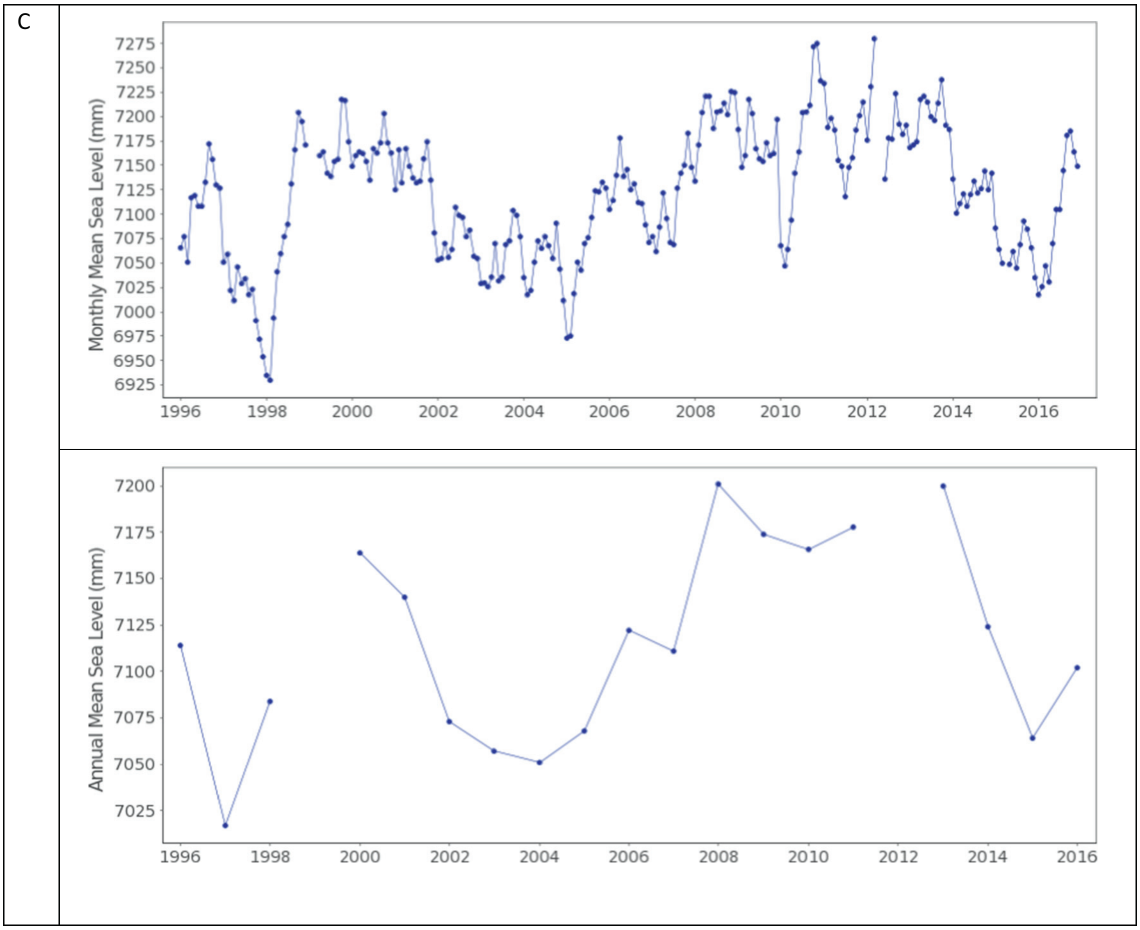

Fig. 5. Monthly and annual mean sea levels of A) Geting, Kuantan; B) Tanjung Keling, Malacca and C) Lahad Datu, Sabah (PSMSL, 2018).

Table 3
Predictions of future climate change.

Source	Model	Prediction
Malaysian Meteorological Department (2009)	GCM with average temperature and rainfall of 1961–1999 as baseline	Projected rise of temperature between 1.0 °C and 3.5 °C and between 1.1 °C and 3.6 °C till 2095, respectively for East Malaysia and the Peninsular Malaysia. No definite trend of precipitation had been captured due to highly variable precipitation-modulating factor. Ensemble rainfall projection showed increased precipitation over the West Coast and decreased precipitation over the East Coast of Peninsular Malaysia in the 21st century. Significant increase of rainfall over western Sarawak had been predicted by the end of the 21st century.
	PRECIS	Annual average temperature was predicted to increase significantly while annual rainfall was predicted to decrease significantly in 2028, 2048, 2061 and 2079. The temperature for Peninsular Malaysia was projected to increase in the range of 2.3 °C to 3.6 °C and for Sabah and Sarawak, from 2.4 °C to 3.7 °C, by 2099. For rainfall, negative anomaly had been predicted for Malaysia from 2050 until 2080, after which rainfall was predicted to increase nationwide.
Sammathuria and Ling (2009)	PRECIS	Annual average daily surface temperature was simulated to increase over Peninsular Malaysia, Sabah and Sarawak in the 21st century while annual rainfall was foreseen to decrease until nearing the close of the century during which increase was expected.
Loh et al. (2016)	PRECIS	Temperature increase in the ranges of 2.5–3.9 °C, 2.7–4.2 °C and 1.7–3.1 °C for three respective emission scenarios (A2, A1B and B2) nationwide by the end of the 21st century was simulated. High variability of rainfall was predicted with drier months of December to May and wetter months of June to November.
Syafrina et al. (2017)	Advanced weather generator	Increase in hourly and 24-hr extreme rainfall was likely between 2081 and 2100 with wider spatial distribution, based on the RCP 6.0 scenario.
Kwan et al. (2013)	PRECIS	Increased probability of extreme rainfall events on the west coast of Peninsular Malaysia from September to November was predicted between 2070 and 2099. Certain zones of the Malaysian Borneo were projected to experience possible early monsoon rainfall. Higher frequency of warm temperature extremes and a slight decrease of cold extremes were predicted.
Amin et al., 2017	GCM for climate projection and watershed hydrology model (WEHY) for hydrologic simulations over Muda and Dungun watershed in the Peninsular Malaysia	The simulation revealed significant increase of mean monthly flows in the Dungun watershed in November from 2030 to 2070, as well as in November and December from 2070 to 2100. For Muda watershed, the increased flow was predicted from April to May and July to October for the period of 2040–2100.

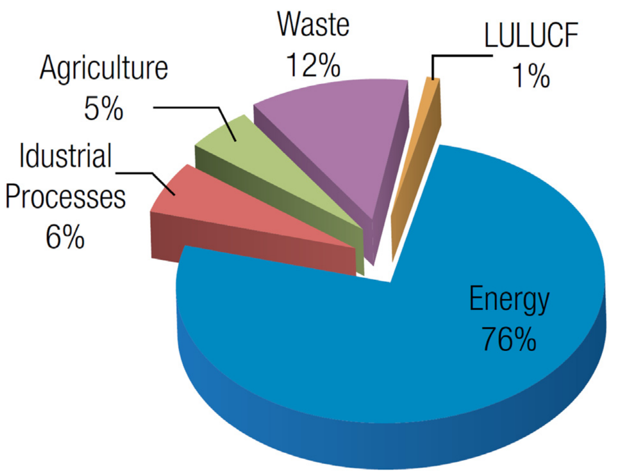

Fig. 6. Major GHGs Emitters in Malaysia (NRE, 2015). Note: LULUCF – land use, land-use change and forestry where GHGs emission comes from commercial harvest, forest fires as well as draining and development of peatlands.

Within the energy sector, the energy industries revolving around energy generation and transmission emitted the largest proportion of GHGs while transportation particularly road transport came in second (see Fig. 7) (NRS, 2001; NRE, 2015). With the upsurge of road vehicles over the years, it is not surprising that road transport constitutes a major GHGs emitter. As of June 2017, a total of 28,181,203 units of road vehicles had been recorded, equivalent to 0.88 vehicle per person in Malaysia. Comparing to the 26,301,952 vehicles in 2015 and 20,188,565 units in 2010, the increase has been dramatic with an average of 1.23 million vehicles added to the road a year (Malaysia Automotive Association, 2018). This was followed closely by energy-related activities of the manufacturing industries and construction though a downtrend was shown after 2008. Fugitive emissions contributed steadily to the GHGs emissions (Solar, 2011; NRE, 2015).

The remaining forest land in Malaysia was a significant carbon sink, removing approximately 85% of the GHGs generated in 2011. Comparing to the forest land, the crop land removed only approximately 5.3% of the GHGs. This implies that forest was still the most significant carbon sink (NRE, 2015). Besides, the role of crop land as carbon sink is controversial as agricultural soil alone produced marginally higher GHGs than those removed by crop land in 2011, thus, indicating that crop land could be a net contributor of GHGs (Fitzherbert et al., 2008; Laurance et al., 2010). Malaysia has more frequently been on the side of net carbon emitter than carbon sink since 1994 (see Table 4).

Table 4
GHGs emission for years 1994, 2000, 2005 and 2011 (NRE, 2015).

Sector	Emission/removals (Gg CO_2 eq)			
	1994	2000	2005	2011
Energy	90,890.33	147,472.09	205,100.14	218,913.63
Industrial processes	4805.41[a]	12,416.23	16,115.77	18,166.34
Agriculture	9886.82	11,699.10	13,845.80	15,775.30
LULUCF (emissions)	153,970.04	22,359.79	25,666.67	2489.67
Waste	18,005.26	24,115.89	27,934.73	34,885.04
Total emission	277,557.86	218,063.10	288,663.11	290,229.98
Total sink	−241,115.10	−250,927.51	−257,794.46	−262,946.41
Net emission	36,442.76	−32,864.41	30,868.65	27,283.57

[a] Data is limited to cement production.

3.8. Mitigation of climate change

Mitigation of and adaptation to climate change also occupy the central theme of the overarching study of climate change. Mitigation aims to reduce or limit the extent of climate change by abating or ameliorating the anthropogenic factors of climate change, for instance the GHGs. Adaptation, however, focuses on minimizing the damage caused by or tapping into the opportunities associated with climate change via prediction of its trends and impacts (Martínez et al., 2018).

The Malaysian government recognizes the impacts of climate change and has framed the National Policy on Climate Change in 2009 to promote efficient use of resources and environmental conservation via five principles, i.e. development on a sustainable path, conservation of environment and natural resources, coordinated implementation, effective participation as well as common but differentiated responsibilities and respective capabilities (NRS, 2001). In 2010, the New Economic

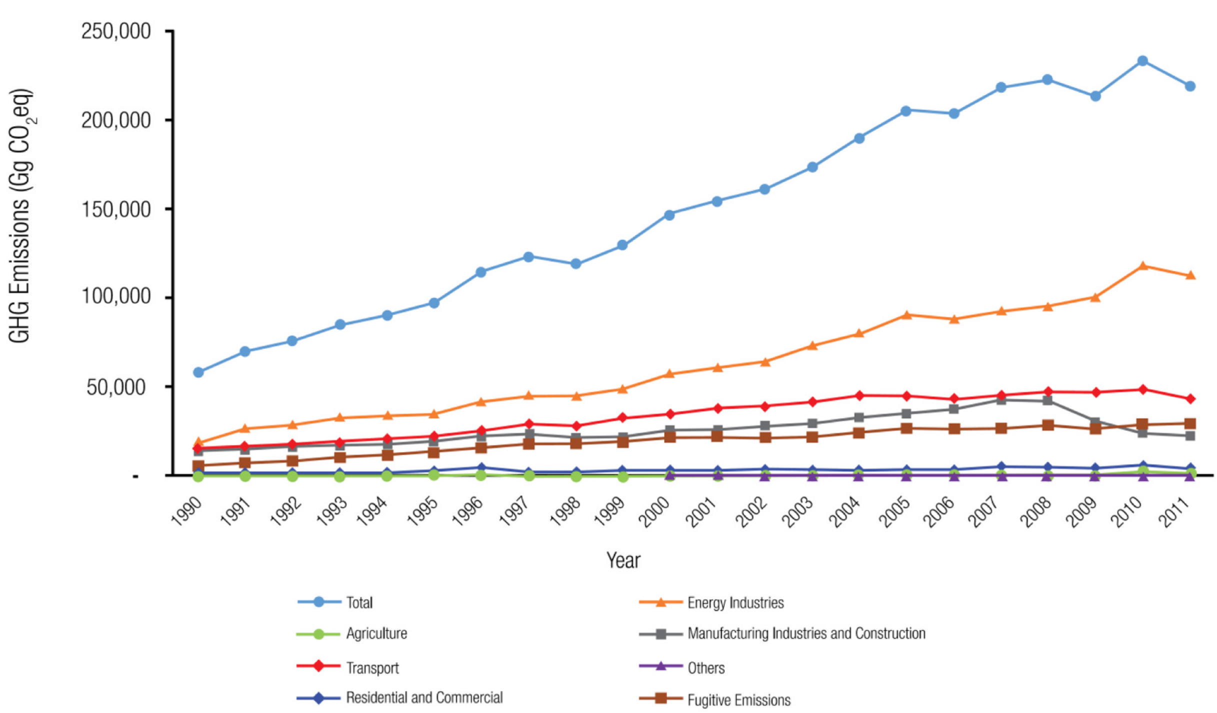

Fig. 7. GHGs emission of the energy sector from 1990 to 2011 (NRE, 2015).

Model (NEM) was introduced to catalyse transformation of Malaysia into a high-income economy in a sustainable manner. The NEM was translated into the Economic Transformation Programme (GTP) targeting to improve the twelve National Key Economic Areas (NKEAs) with those most pertinent to climate change comprising agriculture, palm oil/rubber as well as oil, gas and energy (CSDU, 2017). The climate change mitigating aspects of the pertinent NKEAs are captured in the Malaysian Plans. Taking the latest Eleventh Malaysian Plan (2016–2020) for instance, a strategic thrust on pursuing green growth for sustainability and resilience has been included (EPU, 2015). Despite the emphasis on mitigation of climate change principally via sustainable practices, the National Transformation Programme Annual Report 2017 seemed to focus largely on the economic achievement of the NKEAs (CSDU, 2017).

The Malaysian government has enacted the Efficient Management of Electrical Energy Regulations 2008 to ensure electrical energy is efficiently managed particularly for users or generators of electricity (Yau and Hasbi, 2017). Malaysia is also devoted to the development and use of renewable energy as manifested via the framing of the National Green Technology Policy in 2009 to encourage green energy development and enactment of Renewable Energy Act 2011 to promote renewable energy generation via provision of a special tariff system (CSDU, 2017). Emphasis has also been placed on using energy efficiently in buildings, industries and households via implementing Energy Performance Contracting, increasing public awareness on energy labelling and promoting relevant standards for building such as ISO50001. A noted achievement was an emission saving of about 11 kt CO_2eq of the Federal Government Ministry buildings in 2014 (NRE, 2015). In the same year, installation of methane avoidance facilities was made a requirement by the Malaysian Government on new palm oil mills and upgrading of existing mills (Murad et al., 2010).

Almost concurrent to the development of renewable energy, the development of biofuel came into the limelight. Passing of the National Biofuel Industry Act 2007 shows the national determination to promote the use of B5 (5% biodiesel blending) domestic palm biodiesel. In 2013, Malaysia achieved a 719.76 kt CO_2eq reduction of GHGs emission through the use petroleum diesel and palm oil-based biodiesel blend. In the following year, the bio-diesel B7 programme (7% biodiesel blending) was introduced and B10 programme was then foreseen (NRE, 2015). However, as of 2018, the B10 was only limited to the plantation industries and has yet to be rolled out to the transport sector (Wong and Amarthalingam, 2018).

With road transport being a significant GHGs emitter, much effort has been channelled to mitigate this significant source of GHGs. The National Land Public Transport Master Plan (2012—2030) was launched to enhance planning of public transportation and manage increasing private vehicles. "Low-carbon mobility" to boost public transport usage was also included in the Eleventh Malaysian Plan while the use of compressed natural gas as fuel for taxi and buses, and the promotion of energy-efficient vehicles have been scaled up (EPU, 2015). It was reported that the transportation sector in Malaysia produced close to 50 million mt of CO_2 (equivalent to 50,000 Gg CO_2eq) in 2015 and 85.2% of the emissions came from road transport (Briggs, 2016). While this is parallel to the increasing road vehicles reported by the Malaysia Automotive Association (2018), it does not go in line with the mitigation strategy to reduce GHGs from transportation.

Efficient waste management has been embedded in the Tenth and Eleventh Malaysia Plan via intensification of the Reduce, Reuse, Recycle (3R) programme, expansion of waste treatment capacity, development of new technology and holistic waste management based on life-cycle approach (EPU, 2015; CSDU, 2017). Separation of waste at household-level has been enforced in September 2015 under the provision of the Solid Waste and Public Cleansing Management Act 2007. The waste paper recycling industry hit a milestone in 2013 by reducing emissions amounting to 1993 kt CO_2eq (NRE, 2015). Though 3R has been heavily promoted and waste segregation mandated in certain parts of Malaysia, the awareness remains low among the Malaysian households with recycling rate reported only at 17.5% in 2016 (The Star Online, 2017).

In terms of ecological conservation, the Malaysian government targets to classify 17% of terrestrial and freshwater habitats as protected areas by 2020 while reforesting and enriching degraded forests (EPU, 2015). Under REDD+ Strategy, Malaysia endeavours to keep at least 50% of its land mass forested and this includes regulating sustainability of the palm oil sector through certification schemes such as the Malaysian Sustainable Palm Oil (MSPO) and Roundtable on Sustainable Palm Oil (RSPO) (Laurance et al., 2010; Ab Rahman et al., 2013). Mitigation has also been initiated in the agricultural sector, for instance

Table 5
Summary of mitigation strategies and the expected outcomes.

Sector	Strategy	Expected outcome
General (NRS, 2001)	National Policy on Climate Change, 2009	Promote efficient utilization of resources and environmental conservation.
General, with focus mainly on economic development (EPU, 2015; CSDU, 2017)	Eleventh Malaysian Plan (2016–2020), capturing the national key economic areas derived from the new economic model	Pursue green growth for sustainability and resilience.
Energy (Yau and Hasbi, 2017)	Enactment of the Efficient Management of Electrical Energy Regulations 2008	Ensure efficient management of electrical energy by users or generators of electricity.
Energy (CSDU, 2017)	National Green Technology Policy 2009	Promote green energy development
Energy (CSDU, 2017)	Enactment of Renewable Energy Act 2011	Boost renewable energy generation via a special tariff system
Energy use in buildings (NRE, 2015)	Energy Performance Contracting	Promote efficient utilization of energy in buildings via energy conserving design of new buildings and improvement of energy efficiency in existing buildings.
Energy use in buildings (NRE, 2015)	Adoption of standards such as ISO150001	Certify energy management system that ensures efficient organizational energy use.
Palm oil (Murad et al., 2010)	Installation of methane avoidance facilities	Reduce emission of GHGs particularly methane via improved milling process and biogas capture.
Biofuel (NRE, 2015)	Passing of the National Biofuel Industry Act 2007	Regulate and facilitate the development of biofuel in Malaysia
Transportation (EPU, 2015)	National Land Public Transport Master Plan (2012–2030)	Enhance planning of public transportation and manage increase of private vehicles. It also drives the inclusion of "low-carbon mobility in the Eleventh Malaysian Plan.
Waste management (NRE, 2015; CSDU, 2017)	Reduce, Reuse, Recyle (3R) programme via the Solid Waste and Public Cleansing Management Act 2007	Mandate separation of waste at household level.
Ecological conservation (Laurance et al., 2010)	REDD+	Keep at least 50% of land mass in Malaysia forested.
Ecological conservation and oil palm (Ab Rahman et al., 2013)	Certification schemes, e.g. Malaysian Sustainable Palm Oil (MSPO) and Roundtable on Sustainable Palm Oil (RSPO)	Promote and recognize sustainability practices of the oil palm cultivation.
Agriculture (NRE, 2015)	National Agro-food Policy (2011—2010)	Safeguard sustainability of agro-food industry.
Agriculture (EPU, 2015)	Malaysian Good Agricultural Practices (MyGAP)	Initiate certification and incentive scheme for sustainable agricultural practices

through the National Agro-food Policy (2011−2020) claiming to safeguard the sustainability of agro-food industry but the focus of the policy as reflected by its aims leans towards the social and economic pillars (NRE, 2015). Certification and incentive scheme for the Malaysian Good Agricultural Practices (MyGAP) marks another effort of the Malaysian government to promote sustainable agriculture (EPU, 2015). The mitigation strategies and their expected outcomes are also summarized in Table 5.

3.9. Adaptations to climate change

While the elements of adaptation may have been captured in the National Policy on Climate Change and the Malaysia Plans, they are not as conspicuous as those of mitigation. This could make Malaysia highly vulnerable to the impacts of climate change (Alam et al., 2017). Back in 2011, the areas requiring adaptation have been identified, namely draught, flood and erosion, agriculture, health, forest and biodiversity as well as coastal marine habitat (Solar, 2011). Nonetheless, gaps in adaptation have yet to be filled. Khailani and Perera (2013) identified a lack of participatory planning which was evident in inadequacy of the planners to address critical needs of people in relation to flood hazards for instance, in defining rescue and evaluation routes and reducing the risks of flooding on housing, transportation, infrastructure and utilities. On the positive side, the planners have managed to identify vulnerable zones for buildings and safe zones for emergencies as well as natural line of defence in planning. The study recommended active physical planning involving consultation with stakeholders in the preparation of local development plans by the Federal Department of Town and Country Planning, to incorporate disaster resilience for adaptation to climate change.

With heightening concern towards climate change, there is a danger that any strategies taken by the government to cope with climate change impacts could be viewed as adaptation without really considering the projected climate trends. The Health Ministry initiated the Vector-Borne Disease Control Programme in 1986 which replaced the Malaria Eradication Programme in 1967. The Vector-Borne Disease Control Programme includes the control of not only malaria but other vector borne diseases such as dengue, filariasis, typhus and yellow fever. Its existence has little relation to adapting to and future-proofing climate change but has been claimed to have such aim (Alhoot et al., 2016).

Increasing awareness of the importance of adaptation has propelled participation of Malaysia in adaptation projects, for instance the US Support Programme to the Coral Triangle Initiative to manage coastal and marine resources with biological and economic significance. The initiative also strengthens capacity for policy research on mainstreaming adaptation to climate change in agriculture and water sectors, via research and networking. Malaysia also participated in the Asia Pacific Climate Change Adaptation Project Preparation Facility (ADAPT) to enhance accessibility to funding of climate change adaptation and promote regional knowledge sharing (Gass et al., 2011).

With regards to flooding, the Department of Irrigation and Drainage (DID) Malaysia launched the official web of Public Infobanjir (flood information) which shows the alert and warning water levels based on the records of its flood gauges across the nation to facilitate emergency response. The Infobanjir is in fact a fruition of the flood forecasting and warning system programme initiated by the DID under which the integrated flood and rainfall management (IFFRM) is also parked. The IFFRM comprises two major components, i.e. flood forecasting and monitoring of water resources particularly water quality, drought and debris flow. It aims to mediate response to, hence reduce the impact of flood, in adapting to climate change (DID, 2018). The programme also yielded a drought monitoring website (InfoKemarau) but a visit to the website does not reveal much information available to the public on the occurrences or projections of droughts (DID, 2018). The Malaysia Meteorological Department posts warning of earthquake and tsunami, strong wind, rough sea, thunderstorm, heavy rains and tropical cyclones on its website in light of the increased frequency of extreme weather events associated with climate change. The disaster management centre of the Public Works Department Malaysia also maintains a website which merely relays weather warnings from the Meteorological Department (CFE-DM, 2016).

The adoption of the Integrated Water Resources Management (IWRM) marks an important adaptational initiative of Malaysia leading to the genesis of the National Water Resources Policy in March 2012 (Abdullah et al., 2016). The IWRM stresses on efficient water governance through policy, institutions, participation, information, technology and finance. Major achievements made after adoption of IWRM include passing of laws to enable efficient water supplies and sewerage services, the establishment of National River Register and completion of 12 river basin management plans, as well as publication of the urban storm water management manual. Besides, achievements such as completion of the national study for the effective implementation of IWRM in Malaysia and implementation of IWRM Best Management Practices are also worth mentioning. By 2013, the IWRM had permitted 95.1% of the Malaysian population to have access to piped drinking water in comparison to 94.2% in 2010, while increasing the irrigated area (Abdullah et al., 2016).

At individual level, the fishermen in Malaysia have portrayed different levels of social adaptation. The fishermen surveyed in a study by Md Shaffril et al. (2013) showed highly adapted environmental awareness, attitudes and beliefs, and local environmental knowledge though their knowledge of climate change was limited. The fishermen however developed strong attachment towards the location of livelihood and their jobs. They were not sufficiently accommodative to new skills and opportunities.

Many adapting strategies have been proposed to cope with climate change but a major shortcoming of the strategies is a lack of connection to the strategies that have already been or are being implemented, hence not addressing the gaps. In coping with the impacts of climate change on real estate, Shahid et al. (2017) proposed development of resilient water, power systems and services. This has already been captured in the IWRM. Some strategies could be over-general, hence constraining their operationalization, for instance upgrading poor structure and redesigning storm water drainage (Shahid et al., 2017).

Adaptation of paddy planting is a major concern with rice being the major staple of Malaysians. Eight granary areas in Malaysia have been classified as permanent paddy producing areas to ensure a sustainable level of rice production. Vaghefi et al. (2011) recommended the cultivation of temperature-tolerant cultivars, involvement of the private sector to delineate commercial-scale paddy production zone and cultivation of shorter-maturing varieties. There has been attempt to associate adaptation to ethnic-related paddy yield which underscores the need to facilitate adaptation of the low-yielding group in Malaysia. This form of adaptation is more appropriately viewed as additional effort to increase capacity and competence of the low-yielding group than coping with the overall impacts of climate change on regional agriculture (Alam et al., 2012).

With a multitude of adapting strategies proposed in sectoral climate change studies, it can generally be concluded that adaptation based on future projections of the climate change which also addresses the current gaps by examining the adequacy of existing adaptation policy, planning and implementations would be beneficial. Table 6 provides a summary of the adaptation strategies and their expected outcomes.

4. Conclusion, recommendations and limitations

Climate change in Malaysia is a reality reflected via the historical climate data, particularly of mean daily temperature, mean sea level and records of extreme weather events, as well as simulations of future climate. There are generally two approaches to climate change, i.e. mitigation and adaptation. Having reviewed the actions taken in relation to both approaches, it is obvious that mitigation gets the upper hand.

Table 6
Summary of adaptation strategies and the expected outcomes.

Sector	Strategy	Expected outcome
Public planning (Khailani and Perera, 2013)	Identify vulnerable zones for building and safe zones for emergencies	Better facilitate development planning and increase disaster resilience.
Biodiversity (Gass et al., 2011)	Participation in the US Support Programme to the Coral Triangle Initiative	Better manage coastal and marine resources with biological and economic significance; strengthen capacity for policy research on mainstreaming adaptation to climate change in agriculture and water sectors.
Capacity building (Gass et al., 2011)	Participation in the Asia Pacific Climate Change Adaptation Project Preparation Facility	Access funding to climate change adaptation and promote regional knowledge sharing.
Emergency management (DID, 2018)	Launching of the Public Infobanjur website as part of the flood forecast and warning system programme	Provide alert on water levels to facilitate emergency response.
Water resource management (DID, 2018)	Integrated Flood and Rainfall Management (IFFRM)	Monitor water resources and mediate response to flood.
Water resource management (Abdullah et al., 2016)	Integrated Water Resource Management (IWRM) leading to the inception of National Water Resources Policy in March 2012	Enable efficient water governance through policy, institutions, participation, information, technology and finance.
Real estate (Shahid et al., 2017)	Resilient water, power systems and services	Ensure structural integrity and efficient management of stormwater runoff.
Paddy planting (Vaghefi et al., 2011)	Cultivation of temperature-tolerant cultivars and shorter-maturing varieties	Ensure sustainable yield of paddy and food security as climate warms.

Adaptation, however, should also receive a good share of attention as it increases resilience towards the impacts of climate change.

Though not lacking of mitigating measures, an apparent challenge would be to ensure effective implementation and to monitor the effectiveness of the measures. Efforts to increase segregation of household wastes and recycling, and to encourage sharing of road transport and the use of public transport could be stepped up. With the steady rise of road vehicles annually, a strategic transportation plan to dampen traffic increase and alleviate traffic congestion could come in the pipeline. It is worth to consider revival of the B10 programme and widen the biofuel option beyond palm-oil based to diversify the biofuel sector and regulate the expansion of oil palm sector until sustainability certification schemes of the sector has taken flight. An energy mix with increased proportion of renewable energy could contribute to GHGs reduction but the sustainability of the energy selection should be proven through tools such as life-cycle assessment. With Bakun and Murum hydropower dams now in operation and several other dams proposed in Malaysia, it is crucial to characterize the GHGs emission of the dams and justify the need of hydropower proposals by conducting comprehensive ecological footprint and lifecycle assessment (The Star Online, 2013).

In terms of adaptation, an apparent shortcoming would be limited data or limited public accessibility to data for adaptation at institutional or individual level. Information platforms to enable a closer climatic watch among the fishermen and farmers could be useful to facilitate their adaptation to climate change. With creation of new information platforms, training and capacity building are essential. Continuous and scaled-up effort could be channelled into the existing IFFRM to reduce issues concerning not just flooding but flash-flooding owing to inadequately designed drainage and stormwater system, as climate change projections unveil more rainfalls of high intensity and tropical storms. With drier months projected during the Southwest monsoon season, the IWRM should continue to safeguard and future-proof water security and efficient management of water resources. Malaysia has forged collaborations regionally and internationally in effort to mitigate and adapt to the impacts of climate change. Such collaborations are beneficial for knowledge sharing and securing funding for research in this domain.

While environmental conservation elements have been incorporated into the primary and secondary curricula, and elements of sustainable development at the tertiary level, it is questionable whether the concepts have been successfully internalized and practiced in view of the low recycling rate reported (Tang, 2018). It would be advantageous to look into efficient methods to help students internalize environmental protection values. Last but not least, all visions, policy and plans are futile without effective implementation which in turn, partly relies on enforcement. It is not sufficient to have laws enacted without monitoring and enforcement. For example, open burning is prohibited by the Malaysian law but 2262 cases of open burning were detected by the Department of Environment between January and August 2016, with small open burning cases comprised the highest proportion of the detected cases and open burning of agricultural land followed closely behind (The Star Online, 2016). This implies the need of stricter enforcement and penalty on perpetrators.

In view of a cornucopia of literature related to climate change due to increased interest on regional climate change, this review could face the limitation of not covering all essential literature on climate change though the main themes have been included. Besides, accuracy of the review on temperature increase, rainfall variation, sea level rise and future projections on climate change is dependent on accuracy of the data and simulation models adopted in the literature. Though the data have been validated via cross-checking with multiple sources, it is unlikely to eliminate errors entirely. Completeness of the secondary climate data used is also limited by comprehensiveness of the data at the respective sources.

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